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With the Authors Compliments

ON SOME OF THE

GLACIAL PHÆNOMENA OF CANADA

AND THE

NORTH-EASTERN PROVINCES OF THE UNITED STATES

DURING THE DRIFT-PERIOD.

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Contents.

Glacialized condition of the Laurentine Mountains; and the Drift-deposits of Montreal.—In the Straits of Bellisle, the barren coast of Labrador consists partly of low patches of red sandstones, &c. lying almost horizontally on the Laurentian series—that most ancient system of gneiss and granite which forms the eastern extremity of the great Laurentine chain. These gneissic rocks are rounded and largely mammillated, as if by the action of ice; and all the distant hills, quite bare of trees, possess the same sweeping contours. The gnarled strata of the lofty Bellisle itself, to the very summit, show unequivocal signs of the same abrasion, their well-worn outcrops presenting none of those jagged outlines that all highly-disturbed beds are apt to assume when exclusively weathered by air, rain, and open frost. Similar forms prevail far up the St. Lawrence, on its north shore, easily distinguishable in spite of the forests which, before we reach the Saguenay, rise to the tops of the mountains, leaving here and there unwooded rocky patches. Further up the river, by the Isle aux Coudres (about 50 miles below Quebec), I became more and more impressed by similar appearances. Not a peak is to be seen; and to the top every hill seemed *moutonnée.* Like much of Wales, Ireland, and the Highlands of Scotland, the country appeared *moulded by ice.*

On the south side of the river the country is low, being formed of Silurian strata chiefly covered with drift from the Laurentine chain; and the vast quantity of boulders and smaller stones that cover the land help to impress on it a poor agricultural character.

Approaching Montreal, the gneissic mountains recede to the north-west; and both banks of the river are low, except where an occasional boss of greenstone pierces the Silurian strata. Montreal Mountain, about a mile behind the city, is one of these, rising boldly out of the terraced drift of the plain.

This drift consists of clay, with Laurentian boulders and boulders of greenstone from the mountain, both mixed with subangular gravels of Utica slate and Trenton limestone, which formations rise on its flanks. Many of the boulders and smaller stones are grooved, or more finely scratched, in a manner undistinguishable from the scratched stones of the British and Alpine drift or of Alpine glaciers. We are indebted to Dr. Dawson of Montreal for three important subdivisions of the superficial deposits,—namely, 1st, at the base, lower boulder-clay and gravel; 2ndly, an unctuous clay, with many marine shells, called by him the "Leda-clay" (*Leda Portlandica*), on which lie, 3rdly, beds of gravel and sand, with shells, one of the most common of which is *Saxicava rugosa*. These subformations occasionally pass into each other where they join. The Saxicava-sand he considers to have been a shallow and sublittoral deposit; the Leda-clay to have been accumulated at depths of from 100 to 300 feet or more; and the true boulder-clay to have been formed at an earlier period of subsidence, during which an ocean spread over the greater part of North America. I shall have occasion to show that at one time this sea was, in places, probably over 3000 feet in depth. The section (fig. 1)* across the drift, which I drew at Montreal, nearly agrees with Dr. Dawson's, with the exception that I show five terraces in the drift, while he gives two. Their number may vary in different localities; but they have certainly been formed during the last emergence of the country, each terrace indicating a pause in elevation; and in a great degree the shells of the upper strata lie in a debris of remodelled drift. The two upper terraces, to the left of Dorchester Street, correspond to Dr. Dawson's Leda-clay and Saxicava-sand.

Between the lowest terrace and the river there is a broad marsh, including patches of recent freshwater shells. It is part of the old course of the St. Lawrence; and on its surface (the lighter drift having been removed) the boulders that once studded the clay have been concentrated. Similar terraces occur on the banks of the Ottawa. The country is strewn with boulders of gneiss and metamorphic limestone, from the neighbouring Laurentine chain, mixed with more local debris; and here also it seemed, in several cases, as if, by removal of the lighter material, the boulders were more concen-

* For the Silurian geology of this diagram, I am indebted to the descriptions of Sir Wm. Logan.

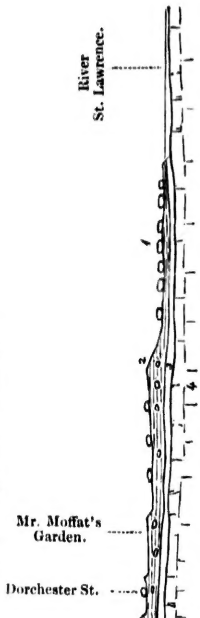


Fig. 1.—*Diagram-section of the Drift-deposits at Montreal.*

1. Marshy ground with concentrated boulders. 2. Drift-beds of clay and boulders, cut into terraces. 3. Utica Slate.
4. Trenton Limestone. 5. Greenstone.

trated on the lower than on the higher terraces. Many of the blocks are rounded; in this respect differing markedly from the majority of those on glaciers, in moraines, and probably from those transported by icebergs, which, derived from glaciers that reach the sea-level, obtain their debris by the fall of rocks and stones on their surfaces from inland cliffs. In the American hills which I saw, there are no signs of true glaciers like those of the Alps having existed; and the boulders have been transported by floating ice from old sea-shores, where they had been long exposed to the washing of the waves.

At Hawksbury Mills I crossed the Ottawa with Sir William Logan, and penetrated part of the Laurentine hills lying several miles from the north bank of the river. Waterworn gravel here and there rises nearly to their summits, now rarely more than 500 or 600 feet above the river.

In the range about eight miles north of the Ottawa, there are well-rounded and occasionally grooved surfaces of gneiss, greenstone, and quartz-rock,—the striations, where I saw them, running 10° and 20° W. of S.

In many places, among the hills, numerous half-rounded boulders (of the same substances as those that strew the plains of the Ottawa and the St. Lawrence) cover the ground, and appear as if they had been waiting their turn for glacial transportation, ere the country was raised above the sea. These general signs existing in this chain, in latitude $45\frac{1}{2}$° N., gave me more perfect confidence in the universal glacial abrasion of the hills on the coast of Labrador in a latitude nearly 150 miles further north.

Glacial Drift of the Plains; Striæ; and Roches moutonnées.—I need not indulge in repeated descriptions of the

drift that covers the plains of Canada and the northern States. It is enough to say that the descriptions given by previous writers are strictly correct. The whole country is literally covered with drift,—to such an extent, indeed, that, except in denuded water-courses and deep gorges, like those of the Genesee and Niagara, it is only in rare cases that the rock is exposed. Even railway-cuttings rarely penetrate to the rocks below. It may be compared, in Europe, to the northern plains of Germany. In horizontal extension it is the most widely spread of all deposits; and even in thickness it rises to the dignity of a great formation, having by Logan and Hall been estimated in places at 500 and 800 feet in thickness†. In all cases the Laurentian boulders, which have often travelled hundreds of miles, are mixed with fragments of the rocks that crop out northward towards the Laurentine hills, and with stones from the strata of the immediate neighbourhood,—the number of the component materials of the drift thus generally increasing to the south‡, marking the fact that the lowlands as well as the mountains have been subject to the denuding and transporting agency of ice. At a distance from the mountains, the boulders become comparatively few; and it is this admixture of calcareous and other material, often lightened with sand, that fertilizes the soil in the great plains that surround the lakes.

The city of Ottawa stands on Trenton limestone; and the surrounding country is strewn with boulders of Laurentian gneiss and Trenton limestone itself, and of Potsdam sandstone, &c.

Between Ottawa, and Prescott on the St. Lawrence, the basement-rock is rarely seen. The country is chiefly covered with gravel containing boulders of gneiss from the hills, and of Silurian rocks from the plains. Here and there are patches of sand containing pebbles and small boulders, generally rounded. In some places it has the appearance of blown sand,—an effect that may have been produced as the land emerged from the sea.

The shores of Lake Ontario, in general, consist of low and shelving slopes of drift; but at Scarborough bold cliffs of sand, gravel, and clay partly white, with boulders, rise 320 feet above the lake. The terraces of Toronto have been described by Sir Charles Lyell. They are like those of the St. Lawrence and the Ottawa. The lower part of the city stands on a very stiff boulder-clay, containing large and small boulders, many of them scratched. Somewhat higher there are beds of beautifully laminated brick-clays, similar to the clay of the Hudson Valley, afterwards to be described, and probably its equivalent. In 1857, great railway-cuttings were in progress in the lower clay. The terrace marked * in fig. 2 consists of sand, with Laurentian and other boulders resting on white brick-clay, which is beautifully laminated, and in which similar boulders are more sparingly scattered.

The removal of the sand by denudation, to form the terrace, has produced a great concentration of gneissic and other boulders on the surface between the terrace and the lake.

In the great plains between Lakes Ontario, Erie, and Huron, the drift of gravel, sand, and clay, with many large and small striated boulders, is frequently of great

† I had an opportunity of examining the drift in many places between Quebec and London (which lies between Lake Huron and Lake Erie), about 500 miles from N.E. to S.W. in a direct line, and from north to south between Montreal and Ottawa, to Blossburg and New York.

‡ See Murray's Report, Geological Survey of Canada, 1856.

Fig. 2.—Section of the Drift-terraces at Toronto.

1. Sand.
2. Sand with boulders.
3. Boulders left after the removal of the sand by denudation.
4. White laminated clay, containing some boulders.

and unknown thickness. White clay occurs round London; from this the bricks are made of which the town is built. The geologist may here travel twenty or thirty miles without seeing rocks in place. In the gravels near Hamilton, elephantine remains were found, supposed by Dr. Dawson to have been washed from the table-land of the Niagara escarpment when the lower plain was still covered by sea.

Between Rochester and Scottsville, the undulating surface consists entirely of drift, containing numerous boulders of Potsdam sandstone, labradorite, gneiss, hypersthene-rock, &c., from the Laurentine Chain about 100 miles off. Many of them are large, smooth, and well striated. Mr. Hall observed that the drift is here often 120 feet thick, and that the mounds are steepest to the north.

The River Genesee runs through a deep rocky ravine, which near Portage is 350 feet high. The rock on the top is smoothed and scratched, and along the whole course of the river, on either side above the gorge, the rocks are generally obscured by drift. On this river Dr. Bigsby observed fragments from Montreal Mountain, which lies 270 miles to the north-east; and Laurentine boulders are common. I observed at Mountmorris, on the river, that in the lower part of the drift the stones are often angular and scratched, while the upper beds are of sand.

Near Portage, on the Genesee, the drift is said by Mr. Hall to be about 500 feet thick, filling up a valley in the rocks, through which an older river ran previous to the drift-period. When the country emerged from the sea, and a new drainage was formed, the river was turned aside by this accumulation, finding it easier to form a new channel in the present gorge, 350 feet deep.

At Onondaga the drift is 640 feet thick.

Drift is equally characteristic of Connecticut and Massachusetts. In the New Red Sandstone Valley of Connecticut, the drift seemed mixed, but mostly local.

It is also well known that large far-transported boulders occur on the south bank of the Ohio,—a circumstance less remarkable than at first sight appears, when we consider that it is stated that icebergs have been seen as far south as the Azores.

Wherever the drift is freshly removed, the rocks are found to be smoothed, striated, and often rounded. On the Isle Perrot, near Montreal, Mr. Billings observed striæ running S.W.; and near Ottawa, by the river, in several places they run south-easterly. These instances are both at low levels; and during a late period it is easy to understand how, during a former extension of the Gulf of St. Lawrence, icebergs drifting up the Gulf, as they do now, would produce scratches running S.W. in the strait between the Laurentine hills and the Mountains of Adirondack, while in the open sea south of Ottawa (now a great plain) the drift passed in an opposite direction. About halfway between Ottawa and Prescott, on the St. Lawrence, near Kempville, the striæ

run S. from 5° to 10° E. on a smoothed surface of Calciferous Sand-rock; and at Niagara, on the limestone, S. 30° W., with minor striations crossing each other at various angles. Near Avon, at Conesus Outlet, in the Genesee Valley, on the Corniferous Limestone, the chief striæ run S. 10° W., crossed by many minor scratches, having a general southern course. These crossings might be expected, if the striæ were produced by floating ice subject to minor variations of the currents, and to the influence of winds. The rock is overlaid by clay containing scratched subangular stones. At Genesee, under 6 feet of drift-clay full of scratched stones, the striæ run S. 5° W.; and near Portage, on the top of the gorge, 350 feet deep, the striæ run a little west of south.

The rocks of the St. Lawrence, where it flows from Lake Ontario, deserve more special notice. Above its junction with the Ottawa, the banks of the St. Lawrence are low and shelving, and the rocks are in general obscured by drift; but between Brockville and Lake Ontario, where the river widens and winds amid the intricacies of the Thousand Isles, while the larger islands are partially covered with drift, and well wooded, the lower islets are often only scantily clothed with grass and a few stunted trees and shrubs. Some of them are formed of Laurentian gneiss, and others of Potsdam sandstone. The Potsdam sandstone above the river-bank at Brockville has been ground smooth, and in waving lines passes under the river. The islands formed of Laurentian gneiss or Potsdam sandstone present the same largely mammillated surfaces, rising from the midst of the river, which between Brockville and the lake gradually increases to 9 or 10 miles in width. All of them are *moutonnées*, somewhat like the islands of Loch Lomond; and the surfaces of the little islets often slip under the water quite smooth and unbroken.

This is one of those cases in which it might be contended that the glaciation of these rocks may be due to the floating ice of the river when it breaks up in spring. But though it may produce slight effects, there are several conclusive reasons why the greater features should not be referred to this cause. The old glaciation has passed up the country quite beyond the reach of the present river, while the tops of most of the islands rise far above the extreme height of the water; and again, some of the islands with well-rounded glaciated surfaces present vertical cliffs to the river, sometimes 20 feet in height, where the rocks have split away at the joints; and on these cliffs I observed no sign of that glaciation which we should expect to find if the river-ice exercised any important influence. Further, it was observed by Sir Wm. Logan, that if the smoothing were produced by river-ice, many of the trees of the islets would be shaved off by the yearly ice,—whereas, when untouched by man, they grow to the water's edge. At the only place I landed (a wooding-station), the rock had been too long exposed to the weather to retain its striations; but as we passed the islands, I could see indications of striæ; and it is to be wished that some one would settle the point by determining their exact bearings, the chief direc-

tions of which, without presumption, I venture to predict will be *across* the river, and approximately from north to south.

Drift and Striæ in the Valley of the Hudson, including the Canaan Hills.—On the banks of the Hudson, south of Albany, the rocks frequently show the familiar mammillated surfaces,—the striations, where I observed them, running nearly north and south. The Highlands of the Hudson also, on a smaller scale, recall the well-rounded outlines of the Laurentine Chain; and at the mouth of the river numerous *moutonnées* surfaces strike the eye, while boulders strew its sides and the surface of Staten Island in the harbour of New York,—all attesting, thus far south, the undiminished energy of glacial action.

Near Boston, gneissic rocks show the same signs; and at Roxburgh, on the outskirts of the city, large surfaces of perfectly *moutonnée* Red Sandstone conglomerate were pointed out to me by Dr. Gould, who informed me that, when he first took Agassiz to the same spot, he at once recognized their ice-smoothed character. The water-worn pebbles of quartz have been ground quite flat on their upper surfaces, and stand slightly out from the rock, the softer sandy matrix of which has yielded to the influence of the weather.

The same kinds of indications are strong in all those parts of Massachusetts, New Hampshire, and Vermont through which I passed. There, as in the other places previously mentioned, the country is much covered with clay, sand, gravel, and boulders, partly rounded and apparently chiefly derived from neighbouring formations. Far-transported boulders may be more scarce among these mountains, their height having partly barred the transport of floating material from the Laurentine Chain, whereas the broad plains south of the lakes were more open to the ice drifting from the north. In the above-named States, instances of fresh and of decaying ice-worn and striated rocks are of constant occurrence in the low ground; and it is truly marvellous to see the same rounded contours rising in the mountains to the very top,—again reminding the traveller of the ice-moulded surfaces of the south-west of Ireland, of the Highlands of Scotland, and of parts of Wales. In none of these American localities are there, however, any signs of pre-existing glaciers, such as are frequent in the mountainous parts of the British Isles.

I am unable to throw any new light on the perplexing question of the glacial phænomena of the Canaan Hills. These have been described by Dr. Hitchcock and Sir Charles Lyell. The range lies on the east side of the Hudson, about twenty miles south-east of Albany, and forms part of the Green Mountains, which are an intermediate part of the long chain that, commencing on the south with the Alleghany Mountains, trends north-easterly to the Mountains of Notre Dame and Gaspé, on the south shore of the Gulf of St. Lawrence. In the district of Canaan and Richmond, their average strike is nearly north and south, the rocks consisting of that part of the Silurian series which ranges between the Birdseye and

Trenton limestones and the Oneida conglomerate,—highly disturbed, cleaved, and partly metamorphosed and foliated. The contours of the hills indicate the moulding effects of ice. The rounded surfaces, wherever they have not been too long exposed to the weather, are grooved and scratched; and these well-defined indications are found alike on the sides and the summits of the hills. In company with Mr. Hall and Sir Wm. Logan, I ascended the Canaan Hills from the N.W., descended into the opposite valley, crossed the Richmond Hills above the Shakers' Village, and, descending into the Richmond Valley, walked to Pittsfield. It is a remarkable circumstance, recorded by Dr. Hitchcock, and partly confirmed by Sir Charles Lyell, and which I also saw, that on both slopes the observed striations run, more or less, *across* the trend of the hills, which at this point strike about N.N.W. The directions of the striæ are between E. 10° S. and S.E.; a larger proportion approaching the first than the second direction. Why they should run *across* the hills and valleys at all has not yet been explained; for, while quite admitting the value of Mr. Darwin's explanation*, it yet does not appear to me to meet a case where the hills are so steep and the valleys so very deep. The difficulty is increased by the fact that the average strike of mountain and valley is from N. to S., which is also the general direction of glacial striations over most of North America; and it is difficult to understand why, if floating ice produced these marks, an exception should have been made in this case, where we might expect the N. and S. run of the submerged valleys would have acted as guides to the icebergs, which would then have floated from north to south as they did in the adjacent valley of the Hudson. The drift is often 40 feet thick and upwards, and is mostly local, many of the boulders being of the Birdseye limestone, which crops out in the valleys. Smaller drift, with these boulders, creeps up the flanks of the hills almost to their summits,—this effect, as stated by Sir Charles Lyell†, having probably been produced in the manner indicated by Mr. Darwin, who, in a similar instance, considers boulders to have been floated up on the ice of successive winters, by little and little during a slow submergence of the country‡.

The Catskill Mountains.—On the west side of the Hudson, the Catskill Mountains rise, in their highest peaks, about 3600 feet above

* Phil. Mag. August 1855.

† Proceedings of the Royal Institution, vol. ii. p. 95.

‡ If before the submergence of the country the cold were sufficiently intense, it is possible that each minor range forming the sides of valleys may have been so completely covered with thick snow and ice, that, always pressing downwards from the snow shed, the striations were formed E. and W., or transverse to the trend of the ranges; but in that case both in the valleys and on the sides and summits of the hills, when fairly submerged, we might expect north and south striations formed by the grating of bergs during the deposition of the northern drift. In the case of isolated hills the striæ ought also to radiate from their summits. I observed none of these appearances, but had not sufficient time to search for them in detail. It is clear that the E. and W. striations across the range were not made by a general terrestrial glaciation during, or after, the re-elevation of the country, for then the boulders, &c. transported from low to high levels would all have been swept down again into the hollows.

the sea, and nearly that height above the river, which is tidal far above Albany. The strike, both of the Silurian and Devonian rocks of the lower hills, is nearly north and south; and, after traversing a broken country for ten or twelve miles, the Catskill Range itself rises in a long north and south escarpment, nearly 3000 feet above the hilly ground that lies between it and the river. At the town of Catskill, striations on the smoothed surfaces run nearly north and south, following the trend of the Hudson Valley between the Catskill and Green Mountains; and at other points between the river and the mountains they run about N.N.E. I was anxious to discover if on the Catskill Mountains themselves there were any signs of true *glacier-action*, this range being much higher than any other elevations which I had an opportunity of ascending. The low country is as much or even more glaciated than Anglesea; and the mountains are as high as Snowdon; and—though in latitude 42° N., whereas North Wales is in latitude 52° to 53°—other conditions seemed very much the same. Observations also in this region were of more importance, since I am not aware that evidences of any kind of glaciation on these heights had previously been definitely recorded. The accompanying sketch-map (fig. 3), constructed on the spot, will give an idea of the topography of that part of the range which I examined.

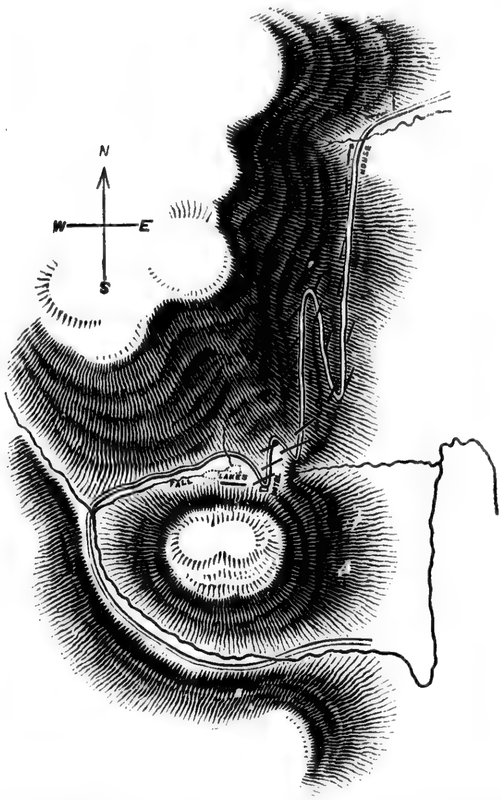
I ascended from the mouth of the valley misnamed "Sleepy Hollow," up the steep and winding road to Mountain House. The mountain is almost everywhere covered by dense wood, so that, except on the roadside, it is comparatively rare to find the rocks uncovered. In "Sleepy Hollow" the road runs nearly east and west. Occasionally local drift lies on its steep northern side; and on the smoothed surfaces of rock I observed a few striations from N. to S., and others from E. to W. The former ran up and down the hill towards the brook; and the latter were on the *vertical* faces of the little cliffs, up and down the valley.

Passing the bend where the road crosses the brook, striations became frequent; and I was surprised to find that all of them ran nearly N. and S. along the flanks of the escarpment, and not from W. to E. down the slope of the hill. For a time I thought that as I ascended higher they would cease altogether; but, so far from this being the case, I was alike pleased and astonished to find that they continued equally strong and frequent up to the plateau on which the Hotel stands, 2850 feet above the sea; *and all, but a few of the last, ran not across, but along the face of the escarpment.*

By twenty compass-observations made on clearly defined striations, the chief grooves run between S. 22° E. and S. 55° W. Among these, one runs S. 22° E., two S. 10° E., two N. and S., one S. 10° W., six S. 22° W., one S. 30° W., two S. 55° W., and one W. 10° N. The variations seem somewhat connected with bends and other irregularities in the face of the great escarpment. One of the observations (S. 55° W.) was made on the well-scratched plateau on which the Hotel stands, about 120 feet above the lower part of

a gorge which here crosses the watershed towards the lakes, in which the stream rises that, further down, forms the Falls of Catskill. The other is at the bend of the road N.E. of the hotel, near the head of the stream. In the lowest part of the gorge, on the summit

Fig. 3.—*Sketch-map of a portion of the Catskill Mountains, showing the Directions of the Striæ near Mountain House.*



of the watershed, many square yards of smoothed rock are exposed a little off the road; and in this plateau numerous main grooves are seen, passing *across* the hill, and nearly at right angles to most of those observed during the ascent, seemingly pointing to the fact that the icebergs, which striated the eastern flanks of the mountains in a N. and S. direction, when the whole was nearly submerged here found a passage or strait, through which they sometimes floated and grated the bottom in a direction quite across that which they were

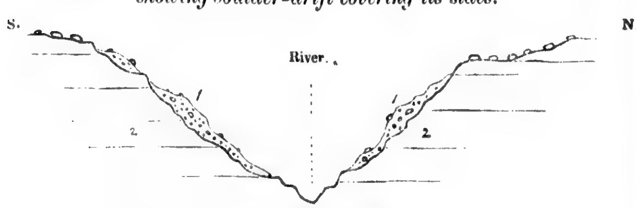
forced to follow when passing along the great escarpment that now faces the Hudson.

Though the principal grooves run in the directions stated, many minor striations, such as might be expected from floating ice, cross them at various angles.

From this point I made two excursions into the higher parts of the range, in the hope of finding similar markings: but so dense is the forest, that it took two hours to walk a mile; and though in several places the rocks were exposed, they were too much weather-worn to afford all the usual indications. Nevertheless the rounded contours of all the mountain-tops always impressed me with the idea of glacial abrasion; and if, as I believe, they were contoured and striated by floating ice, then the drift-sea of the Hudson Valley was at least 3000 feet deep,—and probably more, if, as is likely, the higher peaks were also submerged. Judging by the general uniformity that seems to have prevailed over North America in changes of level, it would probably be safe to infer that this submergence also extended to the Laurentine and other mountain-chains in the eastern part of North America.

Allowing that the striations on the eastern flank of the great range were made by floating ice, it still does not follow that in the interior there should be no traces of glaciers in the narrow valleys on the opposite watershed,—such glaciers, if they ever existed, being like some of those in North Wales, of later date than the emergence of the country from the drift sea. I had an opportunity of testing this. In the gorge close to the south shore of the little lakes, the striations still run W. 10° N.; and below that point the valley, descending westward from 5° to 10°, is covered with boulders of Catskill sandstone (see fig. 3). About a mile and a half down, at the Falls of Catskill, the valley suddenly deepens; and about two miles further it curves round to the S.E. and S.; and finally the stream escapes from the Catskill Range, and flows towards the Hudson. On either side the valley is bounded by high steep slopes and

Fig. 4.—*Section of the Valley below the Falls of Catskill, showing boulder-drift covering its sides.*



1. Drift. 2. Red Sandstone and Conglomerate.

abrupt cliffs; and the height and form of the ground is such that, under favourable circumstances, it seemed as well adapted for the formation of a glacier as many of the valleys of North Wales, had

the conditions for such a result been alike propitious. But the evidence is opposed to any such conclusions. I saw no well-marked *roches moutonnées*, no traces of moraines; and the forest-clad slopes are mostly covered with deep local gravel and boulder-drift, many of the stones in which are scratched. Had a glacier existed there since the drift-period, the drift would have been ploughed out of the valley by the glacier, in the manner that it was removed by the glaciers of the Passes of Llanberis and Nant Francon in North Wales; whereas nothing has been removed, except a portion of the drift by the torrent that now flows in the bottom* (see fig. 4).

Probable equivalency of the Drift of the Hudson Valley with that of Lake Champlain and of Montreal.—I have now a few remarks to offer on a part of the drift itself. South of Albany the Hudson flows through a broad valley full of minor undulations, between the Catskill and the Green Mountains. On the banks of the river are extensive beds of sandy clay, from which the bricks are made of which Albany is built. The city stands on this clay, which extends far down the river towards New York, and northward into the Valley of the Mohawk, and as I shall show, probably also into the valley of Lake Champlain. Beyond the river-bank it stretches E. and W. on the undulating ground towards the mountains, rising, six miles in the direction of the Helderberg, far above the level of the river. At its edge, Mr. Hall pointed out to me that the sands, gravels, and boulder-clay of the ordinary drift pass under it. The superficial deposits of the valley of the Hudson, therefore, consist of two subdivisions: first, the older boulder-beds; and, second, the laminated clay, which at Albany is a thick formation, finely and evenly bedded in layers of 1 or 2 inches thick, the argillo-arenaceous laminæ of which graduate into each other in shades of bluish-grey, brown, and brownish-yellow, producing a beautifully ribanded aspect, and giving the impression of a succession of repeated alternations of tranquil depositions in still water. Boulders occur in it rarely; and the top is covered with sand, which may possibly represent the uppermost sandy beds of the St. Lawrence and Ottawa districts. I searched in vain for fossils, both in the paper-like laminæ of clay, and in the abundant concretions, resembling those of the valley of the Ottawa which contain the fossil fish *Mallotus villosus*.

The Hudson runs nearly straight north and south; and forty miles above Albany, at Sandy Hill, the Champlain Canal joins the river to Lake Champlain, which also trends north and south, and, separated by a low watershed, lies in what must be considered a continuation of the valley of the Hudson. The lake is 90 feet above the level of the sea; and on the Vermont shore, 150 feet above the sea, there is a section of six feet and a half of regularly stratified clay and sand, overlying an older blue clay (the older drift), in which were found, by Professor Zadoc Thompson, *Sanguinolaria fusca*, *Mya arenaria*,

* I was informed by Professor Agassiz, that in the White Mountains, which rise more than 6000 feet above the sea, there are in the higher regions distinct indications of ancient glaciers; and if this be the case, the same phænomena may be looked for in the mountains of Gaspé.

Saxicava rugosa, and *Mytilus edulis*, and at the bottom the bones of a Cetacean associated with *S. rugosa* and a *Nucula* or, more probably, *Leda*. The Leda-clay of Dr. Dawson, at Montreal, is also about 120 feet above the river, or 140 feet above the level of the sea. If the so-called "*Nucula*" of Lake Champlain be *Leda Portlandica*, the Montreal beds contain the same assemblage of fossils (except *Sanguinolaria fusca*). In the Montreal beds Sir Wm. Logan also found a number of the caudal vertebræ of a Cetacean. The beds at Green's Creek, Ottawa, containing the same assemblage of shells, *Mallotus villosus*, and remains of Seals, are 118 feet above Lake St. Peter, and 140–150 feet above the sea. Marine shells (*Saxicava rugosa*, *Mya*, *Mytilus edulis*, and *Tellina Grœnlandica*) occur at Kingston, at the entrance to Lake Ontario. Dr. Dawson shows good reason why the above-named fossiliferous deposits on the St. Lawrence and Ottawa should be considered equivalents. In addition, I am of opinion that this conclusion may be extended to the Kingston beds, and that the beds of Lake Champlain leading down to those of the Hudson are of the same date; and if so, then I cannot doubt that the laminated clay that overlies the older boulder-drift of the Hudson Valley is a larger development of the same formation, the whole having been deposited at the close of the drift-period. In that case, a long marine strait filled the valley of the Hudson, and communicated with the sea that, according to Dr. Dawson, then occupied the whole of Lower Canada south of the Laurentine Chain, and, stretching westward, covered the area of Lake Ontario, and washed the great Niagara escarpment which formed its southern coast.

Probable date of the origin of Niagara Falls.—It has been shown by Mr. Hall and Sir Charles Lyell, that when the Niagara escarpment rose above the water, the Falls of Niagara began by the drainage of the upper lake-area falling into the sea over the edge of the escarpment above Queenstown and Lewistown. It is not improbable that Lake Erie extended at that period much further towards the present Falls; and, agreeing in the general conclusions of these observers and of Dawson, it follows that, if the sea of the Leda-clay washed the base of the escarpment, *the Falls of Niagara commenced during the deposition of that clay, or a little before the close of the drift-period**. If, with accumulated data, the rate of the past recession of the Falls be actually determinable, we shall then be in a condition approximately to show the actual number of years that have elapsed since the close of the North American drift. It may perhaps appear that the approximate period of 35,000 years, given by Sir Charles Lyell for the erosion of the gorge, is below the reality.

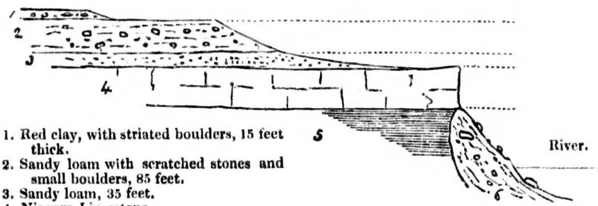
Drift and other Late Tertiary deposits at Niagara.—I have little

* It is well known that the Niagara escarpment is of older date than the drift. Lake Erie is 329 feet above Lake Ontario; and the older boulder-drift lies indifferently on the lower plain and on the table-land. No one has yet attempted to show at what period this old coast-cliff, about 400 miles in length, was formed. The upper platform, on a grand scale, bears the same physical relation to the rocks of Lake Ontario that the Oolitic escarpment and table-land in England does to the Lias and plains of New Red Marl below.

to add to the account of the Later Tertiaries of Niagara given by Sir Charles Lyell and Professor Hall.

Above the falls a terrace of drift with boulders forms the left or Canadian bank of the river. Just before reaching the Horse-shoe Fall, the terraced bank recedes; and a plateau of Niagara limestone lies between it and the edge of the gorge. A road, with a deep cutting in the drift, ascends the slope on the left between Table Rock and Clifton House, at right angles to the river. First there is a gentle slope of 35 feet, then a rapid scarped rise of 85 feet, and behind the railway a second low terrace. The first and second slopes, 120 feet high in all, consist of sandy loam (Nos. 3 and 2 in fig. 5), with scratched stones and small boulders; and the upper terrace (No. 1) is formed of 15 feet of red clay, thinly stratified, also containing angular boulders and scratched stones of Laurentian gneiss, and of Niagara limestones and other Silurian rocks. The top of the upper

Fig. 5.—*Section of the Later Tertiary beds near Niagara Falls.*



1. Red clay, with striated boulders, 15 feet thick.
2. Sandy loam with scratched stones and small boulders, 85 feet.
3. Sandy loam, 35 feet.
4. Niagara Limestone.
5. Niagara Shale.
6. Talus.

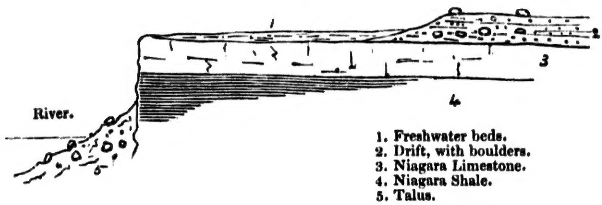
escarpment of drift forms the highest part of the whole plateau. Being 135 feet above the edge of the fall, its top is 60 feet above Lake Erie, which is only 70 feet above that edge. The edge of the great escarpment above Lewiston is said by Mr. Hall to be 70 feet above the top of the fall; and therefore the escarpment No. 1 of the accompanying diagram (fig. 5) is also 65 feet, and No. 2, 50 feet higher than the top of the escarpment above Lewiston, and 45 feet above Lake Erie. If this drift once extended across the space now occupied by the gorge, as shown by the dotted lines, Lake Erie may originally have extended thus far, and after a time the river gradually cut out a channel in the drift and formed both terraces; or else an original terraced channel existed, formed during the emergence of the country, the terraces being formed by marine denudation*.

The lower terrace has, in part at least, been excavated by the river, which, before the formation of the gorge, here spread into a

* It deserves to be stated, that half-way up the cutting, on the surface, I found a *Cyclas*; and another was found by Sir Wm. Logan, with whom I measured the section, on the same terrace, behind Clifton House. Some bits of plate of the "willow-pattern," however, lay near my shell; and that found by Sir Wm. Logan was on ground that had been stirred with the spade; and we came to the conclusion that the evidence they afforded was of very doubtful value.

broad reach, like that above the Falls. It is on a continuation of this platform, about a quarter of a mile below Clifton House, between the drift-terrace and the edge of the gorge, that the strata containing existing river-shells occur (fig. 6).

Fig. 6.—*Section showing the position of the Freshwater beds above the Gorge of the Niagara.*



This drift-terrace Sir Charles Lyell has shown to be as old as the Mastodon-period. The freshwater beds lie in a shallow hollow on the limestone. They consist of remodelled drift, and some of the stones are scratched; but whether the scratches made in the older drift-period have not been worn away, or whether the stones were scratched by river-ice is uncertain. The floor of Niagara limestone is here deeply furrowed, the striations and minor scratches crossing each other at various angles; but the majority run S. 30° W. They follow the general direction of the other striations of the country, that underlie the drift.

On Goat Island, Sir Wm. Logan and I observed that the fluviatile strata lie on drift,—a circumstance, I believe, not previously noticed. It consists, at the base, of sand; and above, of clay horizontally and evenly bedded, containing scratched stones and boulders. As shown in Sir Charles Lyell's diagram*, at the eastern end of the island the Niagara limestone rises a few feet above the river, in the still recesses of which are numerous living shell-fish. Between this point and the summit of the island overlooking the Falls, there is a gradual fall of 15 feet, showing the slope of the river-bed when Goat Island was covered with water. The drift at this point is 29 feet thick, and the freshwater beds above 10 feet, giving 39 feet for the height of the island above the water at the edge of the Falls. Allowing a dip of 25 feet in a mile for the general dip of the limestone, Goat Island was covered with water when the Falls were probably about one mile and a half further down than at present. With regard to the retrocession of the fall, as might be expected, its rate is fastest when the body of falling water is greatest, this cause of waste being far more powerful than the winter's frost. Towards the base of the edges of the Horse-shoe Fall, and at the American Fall, blocks of limestone are accumulated in great heaps, while in the middle of the Horse-shoe Fall the turmoil is so great that it scoops

* Travels in North America, vol. i. p. 37.

out the shale beneath so deeply that the great fallen blocks are lost in the abyss. Where the body of water is small in the American Fall, the edge has only receded a few yards (where most eroded), during the time that the Canadian Fall has receded from the north corner of Goat Island to the innermost curve of the Horse-shoe Fall.